“Headways, Headaches, and Throughput: Applying TOC in Hyderabad Metro Rail’s Operations & Management Accounting

A Case Study

ABSTRACT

This realistic teaching case explores how the Theory of Constraints (TOC) framework can be applied to optimize urban metro operations in the face of external cost shocks. This uses a hypothetical yet a Realistic Hyderabad Metro as a focal example. Specifically, the case examines the impact of a 20% rise in energy prices on corridor-wise throughput per constraint minute (TPCM), highlighting shifts in profitability and resource prioritization. Using real-world parameters such as energy consumption per kilometre, ridership patterns, and fare structures, the case demonstrates how marginal costs affect operational efficiency across corridors of varying lengths and loads. Students are tasked with recalculating TPCM rankings before and after the price hike, evaluating whether to reschedule maintenance windows or reduce off-peak train frequencies. The case reinforces core TOC principles—identifying and exploiting bottlenecks, elevating constraints, and avoiding suboptimal local decisions—while provoking strategic thinking on sustainable transit planning under cost volatility

Theory of Constraints Course

"Headways, Headaches, and Throughput: Applying TOC in Hyderabad Metro Rail's Operations & Management Accounting"

If you do not understand a system, then its effect will always surprise you-Eliyahu Goldratt

Hyderabad Metro Rail operates three lines/corridors under a PPP structure (Concessionaire: L&T Metro Rail Hyderabad Ltd., Public Agency: HMRL). While the network has scaled up and ridership is growing, profitability remains fragile. The CFO argued for traditional cost allocation to determine per-km and per-passenger costs, while the COO and Strategy Head argued for a TOC + Throughput lens to make corridor-wise headway, rolling-stock allocation, and commercial space monetisation decisions. Further the stretch between Gandhi Medical College Metro Station and Mettuguda Metro Station is yet to be operationalized on a regular basis.

The key operational challenges that were debated during a Board meeting with stakeholders. All the managers of all the three corridors A, B and C were present

- Peak-hour signalling constraint on Corridor A i.e. blue line (maximum trains per hour).
- Platform dwell time & AFC gate capacity at high-demand stations (e.g., Ameerpet, Miyapur, LB Nagar).
- Limited rolling stock to distribute across corridors.
- Slow pipeline of non-fare/commercial revenues due to long approval & fit-out cycles (a *non-operational*, but cash throughput constraint).
- Energy tariffs rising; variable traction cost is now material.
- Ridership-price elasticity uncertainty.

The COO who was shaken during the Board Meeting told the key stakeholders that "While operational constraints (like signalling and platform capacity) are visible, a hidden but critical constraint in Hyderabad Metro's financial performance lies in non-fare revenue realisation. Despite having 2 lakh sq. ft. of leasable commercial space, only 60% is monetized due to slow approvals, fit-outs, and tenant onboarding".

The Commercial Development team Head reiterated and addressed "We faced resource constraints in processing retail approvals, with capacity to clear only 10,000 sq. ft. per month, and each 1,000 sq. ft. requiring 2 person-days of coordination (design, safety, legal, vendor fit-outs)". He briefly explained the data analysis

The data for analysis is given below (as much as real from multiple reports)

- Revenue per 1,000 sq. ft./month: ₹2.2 lakh (on average, across retail, ads, kiosks)
- Approval capacity per month: 10,000 sq. ft.
- Time per 1,000 sq. ft.: 2 person-days
- Currently unutilized space: 80,000 sq. ft.

- Time per approval unit (constraint metric): 2 days for ₹2.2 lakh/month → ₹1.1 lakh/day

Network Snapshot (Simplified, for classroom use)

Corridor	End-to-End Distance (km)	Peak Demand Share	Current Peak Headway (mins)	Signalling Max tph	Avg. Fare / Pax (₹)	Avg. Pax / Train (Peak)	Non-fare Rev / Pax (₹)
A(Blue)	27	50%	4	18	28	900	5
B(Green)	16	30%	6	12	24	700	4
C(Red)	29	20%	8	10	26	500	3

Operating Assumptions (per train one-way trip):

- Variable traction & wear cost: ₹90 per train-km
- Crew + Maintenance variable component: ₹15 per train-km
- Total variable cost per train-km: ₹105
- Fixed O&M cost per day (system-wide): ₹1.6 crore
- Train set availability (peak): 44 train sets
- Commercial area available: 200,000 sq ft; leased/activated: 60%

Throughput Accounting Set-up

- **Throughput (T)** = **Farebox + non-fare revenue** − **Truly variable costs** (energy, wear & tear, variable staff, etc.)
- **Investment (I)** = Rolling stock, stations, unfinished commercial space (inventory-like from TOC viewpoint).
- **Operating Expense (OE)** = All other fixed costs (control centre, admin, depreciation treated as period expense in TA, etc.)

Identifying the Constraint(s)

There were two prime constraints that emerged emerge

1. **Operational Constraint**:
    - Signalling capacity on Corridor A (max 18 tph) → limits headway reduction, thus train paths per hour are scarce.

- Platform dwell time and AFC gate throughput during peak hours at interchange stations.

2. **Commercialisation / Cash Throughput Constraint**:
    - The rate of activating non-fare revenue (retail, advertising, TOD) is limited by fit-out/approval cycles.

Sample Computation

The data given above was used to compute Throughput T per Constraint Minute

Throughput per train path (dispatch) on each corridor at peak

Per train (one way) numbers (illustrative):

1. Revenue per train
    - Corridor A: (₹28+₹5)×900pax(₹28 + ₹5) × 900 pax(₹28+₹5)×900pax = ₹29,700
    - Corridor B: (₹24+₹4)×700pax(₹24 + ₹4) × 700 pax(₹24+₹4)×700pax = ₹19,600
    - Corridor C: (₹26+₹3)×500pax(₹26 + ₹3) × 500 pax(₹26+₹3)×500pax = ₹14,500
2. Variable cost per train
    - Cost/train = Distance × ₹105 per km
    - A: 27 × 105 = ₹2,835
    - B: 16 × 105 = ₹1,680
    - C: 29 × 105 = ₹3,045
3. Throughput per train (T/train)
    - A: ₹29,700 − ₹2,835 = ₹26,865
    - B: ₹19,600 − ₹1,680 = ₹17,920
    - C: ₹14,500 − ₹3,045 = ₹11,455
4. Constraint time used per train (proxy): headway window
    - If Corridor A headway = 4 mins, every dispatched train “consumes” ~4 constraint minutes.
    - B @ 6 mins, C @ 8 mins (their own peak constraints).
5. Throughput per constraint minute (TPCM)
    - A: 26,865 / 4 = ₹6,716 per constraint min

- B: 17,920 / 6 = ₹2,987 per constraint min
- C: 11,455 / 8 = ₹1,432 per constraint min

=> Under a system-wide rolling-stock limitation, or where signalling time slots are scarce, TOC recommends prioritizing Corridor A's train paths in peak.

As the Hyderabad Metro project faced delays, cost escalations, and resource bottlenecks, the role of financial leadership became increasingly critical. Traditional accounting methods were inadequate to support the dynamic, constraint-driven realities of such a complex infrastructure system.

In a reflective conclusion to the Board Meeting during the review, the CFO posed a pivotal question to the leadership team:

"Are we measuring what really matters for system and project flow as well as public value, or are we simply tracking how much we've spent?"

The CFO's insight forces a re-evaluation of:

- Whether ***investment decisions*** are aligned with the project's bottleneck;
- How ***buffer management*** can reduce uncertainty in costing and scheduling;
- And how ***financial reporting*** can evolve from static budgets to dynamic constraint-based performance metrics.